Poly Met Mining, Inc. Groundwater Nondegradation Evaluation - Preliminary MPCA Determination

Overview

The MPCA staff has reviewed the potential effects on groundwater quality of the Poly Met Mining, Inc. (PolyMet), NorthMet Project (Project) proposal to mine and process ore for copper-nickel and platinum-group elements. The review considers the requirements set forth under Minnesota Rules Chapter 7060 to preserve and protect underground waters (groundwater) of the state by preventing any new pollution and abating existing pollution.

The Project site consists of three main areas: the Mine Site, Plant Site, and Transportation and Utility Corridors (see Large Figure 1, Vol. 1, NPDES/SDS Permit Application). The Plant Site is located approximately two miles north of the City of Hoyt Lakes in St. Louis County, Minnesota, on the former taconite processing facility and tailings basin previously operated by LTV Steel Mining Company (LTVSMC). The Mine Site is located approximately six miles from the Plant Site, south of the City of Babbitt in St. Louis County, Minnesota. The Transportation and Utility Corridors connect the Mine and Plant Sites. PolyMet proposes to conduct mining operations for 20 years and to generate approximately 308 million tons of waste rock, exclusively at the Mine Site. Following mining operations, activities related to site closure, reclamation, and water management would continue for a period of up to 50 years or longer, as needed, to achieve applicable water quality standards. The project underwent environmental review, culminating in a Final Environmental Impact Statement that the Minnesota DNR found adequate in 2016.

After careful review of the Project information, including modeling contained in the Final Environmental Impact Statement (FEIS), the MPCA staff has determined that due to a combination of controls and mitigation measures (such as engineering controls, wastewater treatment and water monitoring activities) that are part of the Project design, the proposed Project satisfies the requirements under Minnesota Rules 7060 for protection of groundwater resources.

Groundwater Protection

Because the Project has the potential to degrade groundwater through the leaching of metals, sulfate and other solutes from mining operations at the Mine Site and Plant Site locations, MPCA evaluated the potential impacts of the project according to its rules applicable to underground waters in Minnesota Rules chapter 7060. Minn. R. 7060.0200 states, in part:

> *"It is the policy of the MPCA to consider the actual or potential use of the groundwater of the state for its use as a potable water supply and to protect groundwater for this purpose for present and future generations…".*

Minn. R. 7060.0400 further states, in part:

> *"The waters of the state are classified according to their highest priority use, which for underground waters of suitable natural quality is their use now or in the future as a source of drinking, culinary, or food processing water…".*

Minn. R. 7050.0221 identifies the specific water quality standards for Class 1 waters of the state used for domestic consumption, including those applicable to groundwater. This rule states, in part:

> "The class 1 standards in this part are the United States Environmental Protection Agency primary (maximum contaminant levels) and secondary drinking water standards..."

In addition to the primary maximum contaminant levels (MCLs) and secondary maximum contaminant levels (MCLs) promulgated by the EPA, the Minnesota Department of Health has adopted Health Risk Limits (HRLs) for drinking water. HRLs are not adopted as state water quality standards, but they reveal potential health risks to consumers of untreated groundwater. Not all parameters evaluated have applicable drinking water standards or HRLs.

Minn. R. 7060.0500 identifies a Nondegradation Policy applicable to underground waters of the state:

> *"It is the policy of the agency that the disposal of sewage, industrial waste, and other wastes shall be controlled as may be necessary to ensure that to the maximum practicable extent the underground waters of the state are maintained at their natural quality unless a determination is made by the agency that a change is justifiable by reason of necessary economic or social development and will not preclude appropriate beneficial present and future uses of the waters."*

These state rules for Underground Waters do not identify a specific review procedure or methodology that must be applied to demonstrate compliance with the nondegradation policy. Without a specific prescriptive approach in rule, this groundwater nondegradation analysis for the Project will focus on the engineering controls incorporated into the Project design, the resulting protection of the designated uses of groundwater, and the minimization of degradation of groundwater quality from its natural quality. This review focuses on Project activities that may affect the use of groundwater in the Embarrass and Partridge River watersheds downgradient of the Project as a source of drinking water, both now and into the future.

The potential effects of Project activities on surface water quality are addressed in the MPCA's antidegradation review of this Project (Poly Met Mining, Inc. Antidegradation Evaluation – Preliminary MPCA Determination).

Mine Site

The following is a general overview of groundwater flow at the Mine site. A more detailed description and analysis of the hydrogeological setting at the Mine Site can be found in Part C of Appendix A.

The Mine Site is located adjacent to a watershed divide with groundwater from the Mine Site flowing predominantly to the south towards the Partridge River and its tributaries (see Fig. 5.2.2-7, FEIS). The surficial groundwater at the Mine Site is of primary concern because of its shallow depth from the surface and its relatively high potential to transport solute contaminants within the surficial outwash and boulder deposits contained within due to their higher hydraulic conductivity. In contrast, the underlying fractured bedrock has a much lower hydraulic conductivity and is therefore less likely to be impacted by Project activities or to affect downgradient aquifers.

As discussed in Appendix A, surficial deposits in this area are relatively thin. This results in shorter surficial groundwater flow paths prior to groundwater discharge to downgradient surface waters. Although it is not a focus of this review, measures taken to protect the surficial groundwater will also have the effect of protecting the surface water to which it discharges.

Proposed mining operations at the Mine Site include the excavation and stockpiling of ore and the resultant surface mine pits. Mine Site activities with the potential to negatively affect groundwater quality include the mine pits, temporary and permanent waste rock and overburden stockpiles, ore storage or handling areas and mine water conveyance and storage features. As noted above, the leaching of metals, sulfate and other solutes from exposed waste

rock, overburden, ore, wastewater ponds, and unsubmerged parts of the mine pit walls could impact mine site groundwater quality.

PolyMet has evaluated the potential for Mine Site activities to affect groundwater quality and has proposed engineering controls as part of the proposed Project to control waste materials and wastewaters to the maximum extent practicable, thereby minimizing potential sources of pollution to groundwater and to protect groundwater, as described below:

1. Permanent Category 1 Waste Rock Stockpile – a groundwater containment system will capture water infiltrating through the Category 1 stockpile and convey it to the Waste Water Treatment System (WWTS) for treatment. A geomembrane cover system will be placed incrementally over the waste rock as it is stockpiled, to reduce the infiltration of precipitation and waste loads to be captured and conveyed to the WWTS.
2. Temporary Category 2/3 and Category 4 Waste Rock Stockpiles and the Ore Surge Pile – engineered low-permeability composite liner systems will be installed beneath waste rock and ore stockpiles to capture stockpile drainage and prevent it from infiltrating downward to groundwater. Stockpile drainage will be collected and routed to the WWTS for treatment. The stockpiles will have operational lives between 11 to 21 years, after which they will be removed and their footprints reclaimed.
3. Overburden Storage and Laydown Area (OSLA) – will have a compacted base layer with low permeability and no separate engineered liner system. Runoff from the OSLA is expected to be of sufficient water quality so as not to require treatment beyond settling to remove suspended solids prior to pumping to the FTB. GoldSim modeling for the FEIS predicted that any infiltration through the compacted base of the OSLA would not adversely affect groundwater quality.
4. Equalization Basins – the Equalization Basins at the Mine Site will have engineered single geomembrane liner systems with a maximum 13-foot operating depth. The basins will be removed and reclaimed as part of the Mine Site reclamation process when they are no longer needed.
5. West Mine Pit – during operations this pit will be dewatered and groundwater will flow inwards towards the pit, thereby having no impact to groundwater quality during mining operations. After mining operations are completed, PolyMet will accelerate the natural flooding of this pit using treated water from the Plant Site WWTS (+/- untreated water from the FTB). As the West Pit fills, water from the pit will be pumped to the WWTS, treated and returned to the West Pit to manage the overall water quality of pit waters prior to groundwater outflow from the pit to the surficial aquifer. At about mine year 48, pit water levels will rise above the bedrock and flow into the surficial groundwater flow path towards the Partridge River. The flooding of the mine pit will control water quality by reducing the oxidation time for the pit wall rock and bringing contaminant constituent concentrations to their long-term steady state concentrations (see Table 5.2.2-20, FEIS).
6. East & Central Mine Pits – during operations the pits will be dewatered and groundwater will flow inwards, thereby having no impact to groundwater quality. After mining is completed, these pits will be backfilled with waste rock from the temporary waste rock stockpiles and from on-going mining in the West Pit and allowed to fill with water, to reduce oxidation in the waste rock and mine pit walls and reduce the potential for groundwater quality impacts. During flooding and for approximately 14 years after flooding is complete, PolyMet will recirculate and treat mine pit waters at the WWTS.

PolyMet has proposed to maintain these engineering controls and conduct groundwater quality monitoring for the duration of the mining operations and through future reclamation and closure activities, as long as necessary to meet groundwater standards (see Table 5.2.2-20 of the FEIS). This approach is consistent with the policy identified in Minn. R. 7060.0200 to protect and conserve groundwater supplies for present and future generations and the prevention of possible health hazards.

Groundwater Modeling Predictions

PolyMet conducted groundwater modeling simulations as part of the EIS process to predict the potential impacts of Mine Site Project activities on groundwater quality for a time period of 200 years from the start of mining operations.

Attachment 4 – Groundwater Nondegradation Evaluation

PolyMet used the GoldSim modeling platform to predict the concentrations of contaminants from mine operations at three downgradient locations: Dunka Road, the property boundary, and the Partridge River (see FEIS Fig. 5.2.2-7). The GoldSim modeling predictions provide the basis for understanding whether the Project activities are likely to be protective of groundwater quality, both now and into the future. The modeling included predictions for 27 solute contaminants that, based on host rock mineralogy and chemistry, had the potential to impact water resources.

PolyMet used the existing groundwater quality conditions as measured in on-site monitoring wells as inputs to the GoldSim modeling. Because the Mine Site does not have any existing development, the existing conditions represent natural background conditions as defined by Minn. R. 7060.0600 subp. 8. Where the natural state of groundwater exceeds state standards, the natural background is treated as the standard for drinking water. Minn. R. 7060.0600 subp. 8. This baseline monitoring indicated that the natural background concentrations of iron, aluminum and manganese exceed the water quality standards (defined by the secondary maximum contaminant levels) established for these parameters.

The GoldSim modeling predictions included both a "Continuation of Existing Conditions" scenario and a "Proposed Action" scenario that allowed a comparison of predicted project impacts against what conditions would be if the project was not built. The modeling predicts that during Project operations and after closure, Project activities would result in small increases in the groundwater concentrations for a limited number of solute contaminants compared to existing conditions. MPCA staff compared the predicted groundwater contaminant concentrations to the drinking water standards (accounting for natural background concentrations). The GoldSim modeling showed no exceedances of applicable drinking water standards or the HRLs as a result of the Project (see Table 5.2.2-23, Ch. 5, FEIS).

Based on MPCA review of the modeling results, PolyMet's proposed Project would not preclude beneficial present and future uses of the groundwater (7060.0500), nor would it cause exceedances of applicable drinking water standards. The Project would allow use of the groundwater as a potable water supply in accordance with 7060.0400. This conclusion is consistent with the findings of the MDNR-approved FEIS (Fig. 5.2.2-26).

Existing Potable Water Supply

Minnesota Rules relating to the nondegradation of groundwater do not directly address the protection of other waters that have a beneficial use as drinking water. However, as noted above, groundwater from the Mine Site enters the Partridge River and then flows to Colby Lake, which is the drinking water source for the City of Hoyt Lakes. To address the indirect effects that any groundwater impacts at the Mine Site activities could have on downstream waters, the GoldSim modeling included predictions of water quality in the Partridge River and Colby Lake. The evaluation determined that solute contaminant concentrations in Colby Lake as a result of the Project would essentially be the same as would occur if the Project were not built, and that concentrations in the lake would not exceed drinking water standards beyond what would occur if the Project did not happen. (FEIS Table 5.2.2-34). This evaluation found that the engineering controls proposed for the Mine Site are expected to protect not only groundwater at the Mine Site, and but also not to contribute to an exceedance in the potable water supply for the City of Hoyt Lakes in Colby Lake. This conclusion is consistent with the goal set forth in Minn. R. 7060 for protection of groundwater for its use as a potable water supply.

Proposed Groundwater Monitoring

The draft permit for the NorthMet Project includes a variety of groundwater monitoring of the surficial and bedrock aquifers at the Mine Site. This includes the continuation of monitoring at existing monitoring wells that were installed for the EIS (which include wells downgradient of proposed Mine Site facilities). New monitoring wells will be added to fill in gaps in the monitoring network, including at locations immediately downgradient of the Category 1 stockpile groundwater containment system. In general, groundwater quality will be monitored quarterly for key constituents (such as sulfate, chloride, copper and nickel) that can serve as "surrogates" for other parameters and annually for a wider range of parameters. The monitoring included in the draft permit is a combination of that recommended by the

FEIS, that proposed by PolyMet in the permit application, and that recommended by MPCA staff. The monitoring as proposed will be effective in verifying that groundwater resources are protected and that they will not be precluded from appropriate beneficial present and future uses.

Plant Site/Tailings Basin

Groundwater quality at the Plant Site/Tailings Basin (Plant Site) has been affected by seepage from the existing ferrous LTVSMC tailings basin. Only a small percentage of this seepage reaches the surficial aquifer; most ends up as shallow seepage that flows to wetlands and small tributaries north and west of the Plant Site that flow towards the Embarrass River (See FEIS Ch. 5, pp. 183-193).

The former LTVSMC tailings basin is currently a primary source of contaminants seeping to groundwater and surface water at the Plant Site. To eliminate this existing source and to minimize contributions from the NorthMet Project, PolyMet proposes to install a groundwater containment system to wrap around the Tailings Basin and capture both the shallow seepage to surface water and the deeper seepage to the aquifer. The containment system would include a low-permeability barrier down to bedrock to cut off surficial aquifer flow from the Tailings Basin. In addition, the system would maintain an inward water table gradient to prevent flow out of the system. Modeling of the containment system conducted as part of the FEIS indicated that little, if any, seepage would bypass the system through fractured bedrock. This is consistent with the information in Appendix A indicating that bedrock groundwater flow at the site, where it exists at all, is believed to be minor relative to surficial groundwater flow.

The seepage containment system, once constructed and operated, would immediately begin to intercept tailings basin seepage and remove it from the groundwater system for treatment at the WWTS. Following treatment at the WWTS, the treated water would be discharged to surface waters downgradient of the containment system; this would also have an immediate beneficial effect on downstream surface water quality. The effects on ground water quality, however, would lag behind those seen in the surface water because of the very slow velocity of groundwater flow relative to surface water flow. In other words, it will take a much longer period of time before the improvements in ground water quality are able to be measured in the monitoring wells located at the property boundary.

Captured seepage would be treated in the WWTS or re-used in Plant Site processing. PolyMet has also proposed additional engineering controls to reduce the potential for seepage through the unlined Tailings Basin that includes the installation of bentonite amendments to the tailings dams, Tailings Basin beaches and pond bottom. These combined engineering controls would abate existing pollution, maximize the possibility of rehabilitating the existing degraded groundwater, and minimize longer term effects to groundwater quality in accordance with the policies set forth in Minnesota Rule 7060.0400.

Groundwater Modeling Predictions

As part of the completed EIS process, PolyMet evaluated the potential impacts of Project activities at the Plant Site on groundwater quality using GoldSim, modeling from the Plant Site to the property boundary (see Fig. 5.2.2-9). As with the Mine Site, the GoldSim modeling for the Plant Site compares the potential Project activity effects on groundwater quality to drinking water standards as well as to a continuation of existing conditions scenario where no Project activity takes place. MPCA staff reviewed the GoldSim modeling predictions for contaminant impacts to groundwater and found that, in general, the concentration of groundwater contaminants with the Project would remain the same or decrease over time, and would be lower than concentrations that would occur if the project was not built. The GoldSim modeling predictions indicate that the Project would not cause exceedances of drinking water standards beyond what would occur with no Project activities. This indicates PolyMet's proposed Project actions at the Plant Site would not preclude appropriate beneficial present and future uses of the groundwater beyond what would occur if the Project was not constructed, in accordance with Minnesota Rule 7060.0500, Nondegradation Policy.

Attachment 4 – Groundwater Nondegradation Evaluation

Proposed Groundwater Monitoring

The draft permit for the NorthMet Project includes groundwater monitoring of the surficial and bedrock aquifers downgradient of the Tailings Basin. This includes the continuation of monitoring at existing monitoring wells near the property boundary and at new monitoring wells to be located just downgradient of the seepage containment system. In general, groundwater quality will be monitored quarterly for key constituents (such as sulfate, chloride, copper and nickel that can serve as surrogates for other parameters) and annually for a wider range of parameters. The monitoring included in the draft permit is a combination of that recommended by the FEIS, that proposed by PolyMet in the permit application and that deemed advisable by MPCA staff. The monitoring as proposed will be effective in verifying that groundwater resources are protected and that they will not be precluded from appropriate beneficial present and future uses.

Summary

PolyMet has proposed a combination of engineering controls and wastewater treatment that are protective of groundwater quality for the proposed Project. PolyMet has also conducted GoldSim modeling simulations that predict the effects of Project activities on groundwater quality; which indicate the Project will not cause exceedances of relevant groundwater quality standards, beyond what would occur if the Project was not constructed. Furthermore, PolyMet has proposed to monitor for potential impacts from Project activities on a recurring basis throughout operations, reclamation, and closure to ensure the protection of groundwater and surface water quality. (Chapter 5, FEIS, pp. 5-8, 9).

Based on a careful review of the Project information listed below, the MPCA staff have determined the proposed PolyMet Project satisfies the requirements set forth under Minnesota Rules 7060 for protection of groundwater resources. The proposed groundwater monitoring included in the NPDES/SDS permit will verify the protection of the groundwater resources.

1. PolyMet NPDES/SDS Permit Application to the MPCA, October 2017 (NPDES/SDS Permit Application). https://www.pca.state.mn.us/quick-links/water-quality-permit-northmet,
2. Final Environmental Impact Statement (FEIS). http://www.dnr.state.mn.us/input/environmentalreview/polymet/feis-toc.html,
3. Poly Met Mining, Inc. Antidegradation Evaluation – Preliminary MPCA Determination
4. Groundwater Concentrations Time Series Analysis, Excel Spreadsheet, Mine Site Version 6.0. Package Volume 2, and
5. Groundwater Concentrations Time Series Analysis, Excel Spreadsheet, Plant Site Version 6.0. Package Volume 2.

APPENDIX A

Poly Met Mining, Inc. Groundwater Nondegradation Analysis - Preliminary MPCA Determination

A. Summary

This report addresses a part of the NPDES/SDS application from the Poly Met Mining, Inc. (PolyMet) for the NorthMet project (Project), which focuses on the potential for contamination of groundwater that could occur from mining, processing and waste disposal activities associated with the Project. Groundwater staff have conducted this review by incorporating elements of the surface water anti-degradation review process, and employing methods commonly employed in various MPCA hydrogeologic investigations. Surface water is protected under antidegradation language in Minnesota Rule 7050 (1), while groundwater is similarly protected under nondegradation language in Minnesota Rule 7060 (2).

This report will provide the reader with a technical overview of the hydrogeology of the PolyMet project area, as well as a review of the groundwater issues raised in the NPDES/SDS permit application directed toward groundwater, using the standard provided on nondegradation in Minnesota Rule 7060.0500. The report concludes with recommendations on potential additional placement of new well(s) in areas not currently monitored. These are areas with preferential groundwater pathways leading from Project facilities to surface water discharge points. Surface water is an important factor in this analysis because the groundwater flowpaths in the project area are short in length, not used as a source of drinking water supplies, and end in nearby streams. This report also recommends methods for identifying when the detection of rising contaminant concentrations in future monitoring data from compliance wells could indicate a potential failure of the engineering systems proposed by PolyMet such that adaptive management or mitigation should be required.

Report assumptions

This report is based on two key assumptions. First, the report concerns itself primarily with the hydrogeology of the site, and not the engineering details that are part of the PolyMet mine process. The report emphasizes the surface water and groundwater watershed boundaries, surficial geologic properties and thicknesses, bedrock geology, presence of geologic contacts and faults, and other issues. This groundwater review will be responsive to questions specifically addressing groundwater issues, as well as individual surface water issues that warrant a groundwater response. Therefore, the applicable standard of review is whether underground waters of the state are maintained at their natural quality to the maximum practicable extent.

The second assumption is that the technical aspects of the report are based on a careful review of the technical resources available to the author through publically accessible datasets and maps. Sources include the Minnesota Geological Survey (MGS), Minnesota Department of Natural Resources, the MPCA, Minnesota Geospatial Commons, and others. It is assumed that the information gathered for this review includes all relevant information available at the time this report was prepared. References to all sources are provided in the references at the end of this report.

B. Background

PolyMet is proposing to develop a mine and associated processing facilities for the extraction of copper, nickel, and platinum group elements (PGE) in northeastern Minnesota. The mine would be the first of its kind in the state. The proposed mining project would be located in the St. Louis River watershed on the eastern edge of the Mesabi Iron Range, about 6 miles south of Babbitt. On July 11, 2016, PolyMet submitted an application to the MPCA for an NPDES/SDS water quality permit for the NorthMet project. The information contained in the permit application is used by the MPCA to determine which state and federal requirements apply. The MPCA reviews the application to determine if it contains all of the information necessary to start processing the application, to ensure the project can meet applicable laws and requirements and preparing a draft permit for public input.

The references in the PolyMet application focused on groundwater can be found in the complete PolyMet NPDES/SDS permit application (6). Within the following volumes are sections devoted to the potential threat to groundwater:

Volume 2 – Mine Site: Section 4.0

The State of Minnesota has a nondegradation policy to protect groundwater in Minnesota Rules, part 7060.0500, (2):

> It is the policy of the agency that the disposal of sewage, industrial waste, and other wastes shall be controlled as may be necessary to ensure that to the maximum practicable extent the underground waters of the state are maintained at their natural quality unless a determination is made by the agency that a change is justifiable by reason of necessary economic or social development and will not preclude appropriate beneficial present and future uses of the waters.

PolyMet's response to 7060.0500 for the Mine site from Volume 2, page 45:

> The available sampling results, as summarized in Section 3.1.2 of this volume, establish that the groundwater at the Mine Site remains in its natural quality. There are no known existing or previous discharges from human activities in the immediate vicinity of the Mine Site, and Mine Site water quality is similar to regional data (Section 4.3.4.1.4 of Reference (4)). Because the Mine Site groundwater remains at its natural quality, PolyMet has designed the Project to comply with the State's groundwater nondegradation policy, including the "maximum practicable extent" requirements of Minnesota Rules, parts 7060.0500 and .0600.

In its application, PolyMet expresses its confidence that groundwater quality will not be degraded by mining activities, due to the use of engineering controls at the Mine Site. PolyMet has committed to keep the concentrations of relevant parameters at or below current, pre-mining levels. Monitoring wells would confirm that the controls are working to their expected specifications. However, the determination of what increase of concentrations of specific parameters would constitute a failure of the engineering systems, and therefore a release of contamination into groundwater, has not been explicitly identified by PolyMet. Therefore, to determine whether there has been a degradation of groundwater, MPCA staff recommend use of a technical process described near the end of this report, designed to identify when a statistically significant change in parameter concentrations has occurred when compared to initial concentrations. If a (increasing) change is statistically significant, it would then indicate a potential failure of engineering controls, and a failure of the effort to avoid nondegradation of groundwater.

Volume 5 – Tailings Basin & Beneficiation Plant: Section 4.0

The PolyMet discussion of nondegradation in the area downgradient of the Tailings Basin starts out in the same fashion as the response to potential Mine site degradation, by referencing Minnesota Rules. However, the conditions at the Tailings Basin located in the Embarrass River watershed, differ from the Mine Site in that the existing water quality

downgradient of the Tailing Basin is degraded due to past iron mining activities at the site. From the PolyMet application, Volume 5, page 38:

> Downgradient of the LTVSMC tailings basin, groundwater does not exist in its natural condition, as a result of seepage of pollutants from decades of ferrous mining activities at the site, including in particular ferrous seepage from the LTVSMC tailings basin..... Where groundwater in its "natural condition" is not present to be protected against degradation, the State's groundwater policy focuses instead on "abating [existing] pollution" and "maximiz[ing] the possibility of rehabilitating degraded waters."(Minnesota Rules, part 7060.0400). The Project's design will have the effect of rehabilitating currently degraded groundwater downgradient of the Tailings Basin in accordance with the policies set forth in Minnesota Rules, chapter 7060 (Section 4.3).

The area downgradient of the legacy iron tailings basin has elevated levels of certain parameters including chloride, sulfate, other major cations and anions, fluoride and molybdenum. (7) PolyMet states on page 38, that:

> Downgradient of the LTVSMC tailings basin, groundwater does not exist in its natural condition, as a result of seepage of pollutants from decades of ferrous mining activities at the site, including in particular ferrous seepage from the LTVSMC tailings basin.

In its application PolyMet states that the engineering controls employed to abate the existing flow of ferrous seepage to groundwater will eventually improve the groundwater quality in the area. PolyMet will monitor paired wells that straddle the new Tailings Basin boundary, to ensure that groundwater flow remains inward, toward the basin. PolyMet states in Section 4.3 of Vol 5, page 39, that:

> PolyMet will monitor the performance of the FTB seepage capture systems and the groundwater quality downgradient of the Tailings Basin (Section 3.2.2 of Volume I), and if the engineering controls are not achieving the desired outcomes, will implement adaptive management actions or contingency mitigation (Sections 6.5 and 6.6 of Reference (1)), as necessary to comply with all permit conditions.

Given this expectation, a statistical method such as the one referenced earlier in the Mine Site section, and fully described near the end of this report could also be applied to the Tailings Basin area. As with the Mine Site, PolyMet is pledging to keep the concentrations of relevant parameters at or below current levels. In the case that concentrations of parameters of concern are reduced as PolyMet predicts, there would be no need to determine a statistical difference from initial conditions, because groundwater is not being degraded. However, were concentrations to have increased to a level that is determined to be statistically significant when compared to pre-PolyMet mining levels, then groundwater degradation will be identified.

Volume 6 – HRF & Hydrometallurgical Plant: Section 4.0

The PolyMet discussion of groundwater nondegradation downgradient of the Hydrometallurgical Residue Facility (HRF) is similar to the approach taken for Volume 5, for the Tailings Basin. Volume 6 states:

> .....groundwater downgradient of the HRF has been discernably impacted by previous ferrous mining activities and does not reflect natural quality.

Therefore, the Agency approach to identifying a release of contaminated groundwater that would constitute a failure of engineering controls for the HRF and Hydrometallurgical Plant will be the same as for groundwater downgradient of the Tailings Basin.

C. Hydrogeological Setting of the PolyMet Site

Project Area Location

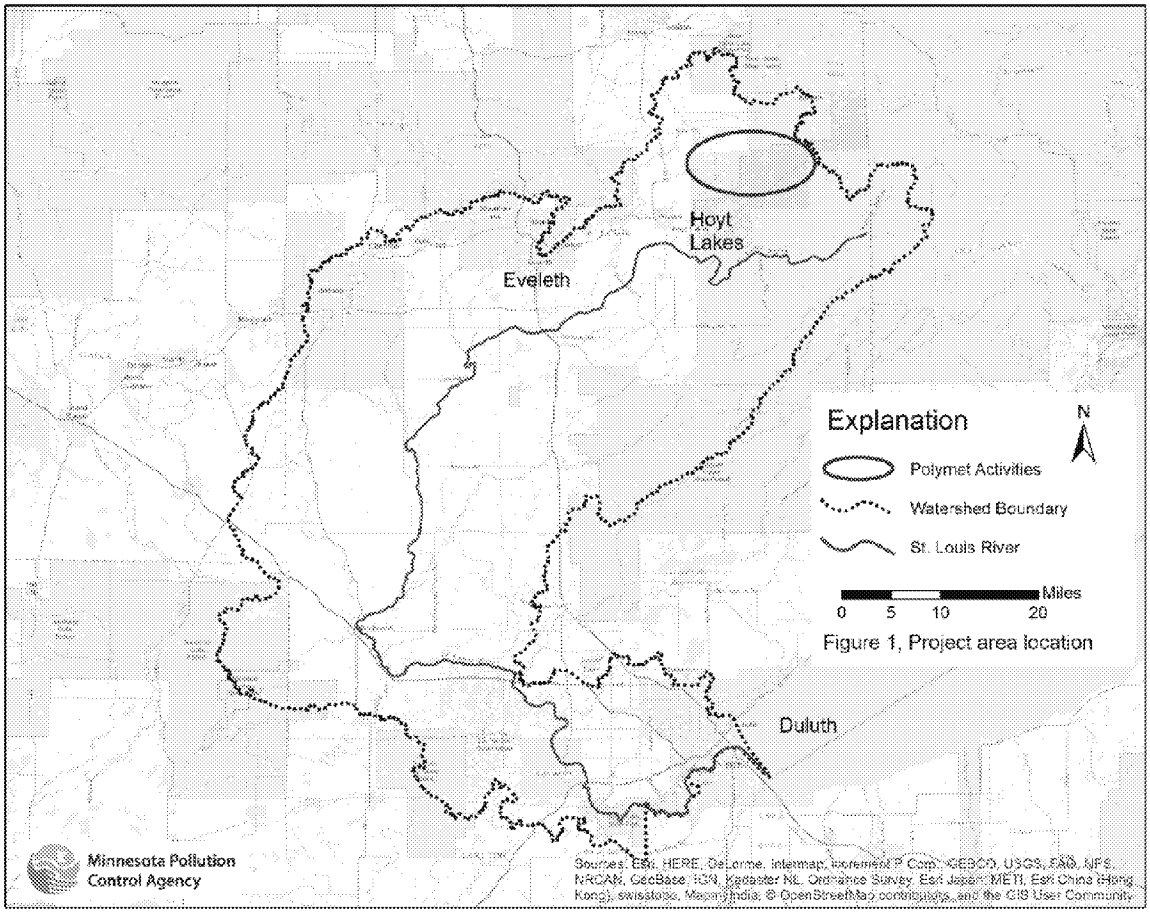


Figure 1, Project area location

The PolyMet site is located south of the city of Babbitt and north of the city of Hoyt Lakes in St. Louis County, Minnesota (Figure 1). The site is located in the upper St. Louis River Watershed.

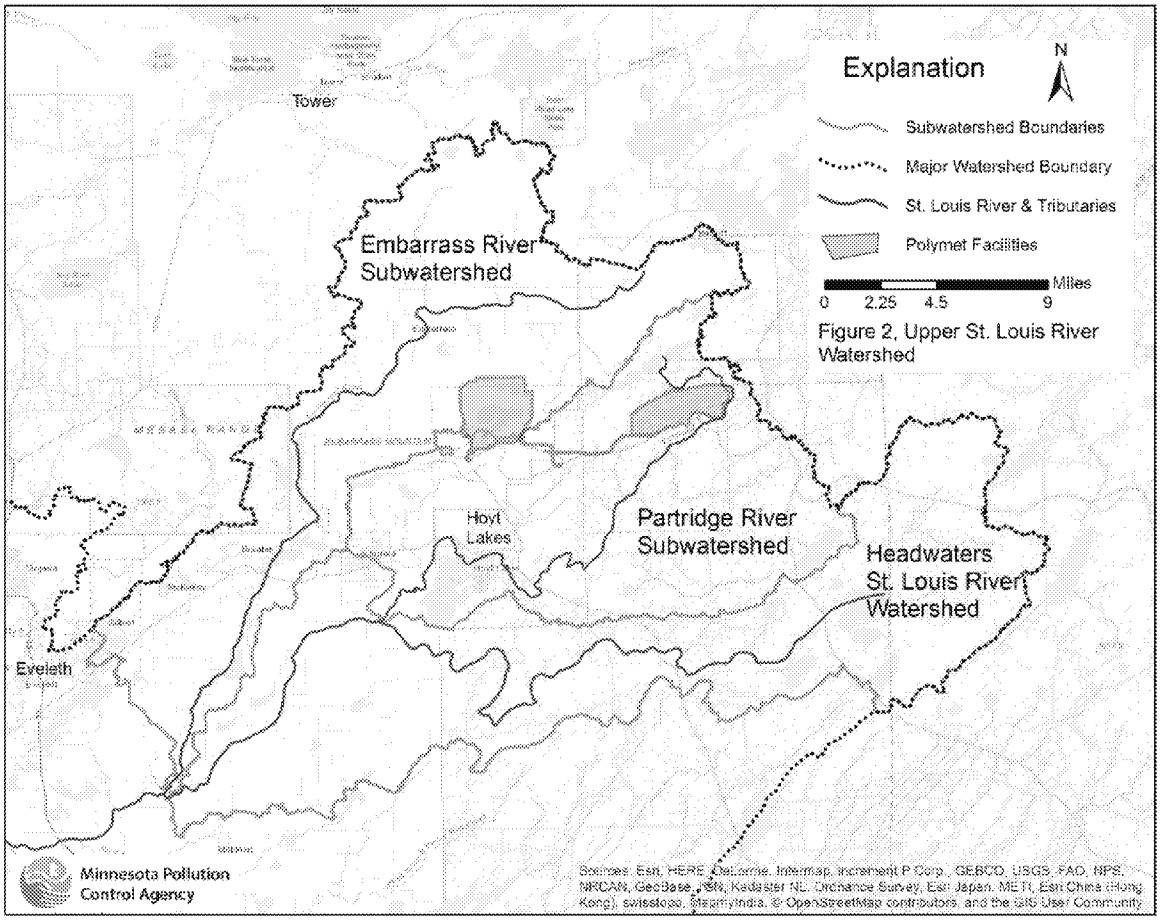


Figure 2, Upper St. Louis River Watershed

The St. Louis River flows 192 miles down more than 1,000 feet of elevation before reaching Duluth and Lake Superior. Figure 2 shows a close-up of the upper watershed, with the three subwatersheds closest to the PolyMet site: the Embarrass, the Partridge, and the St. Louis River Headwaters.

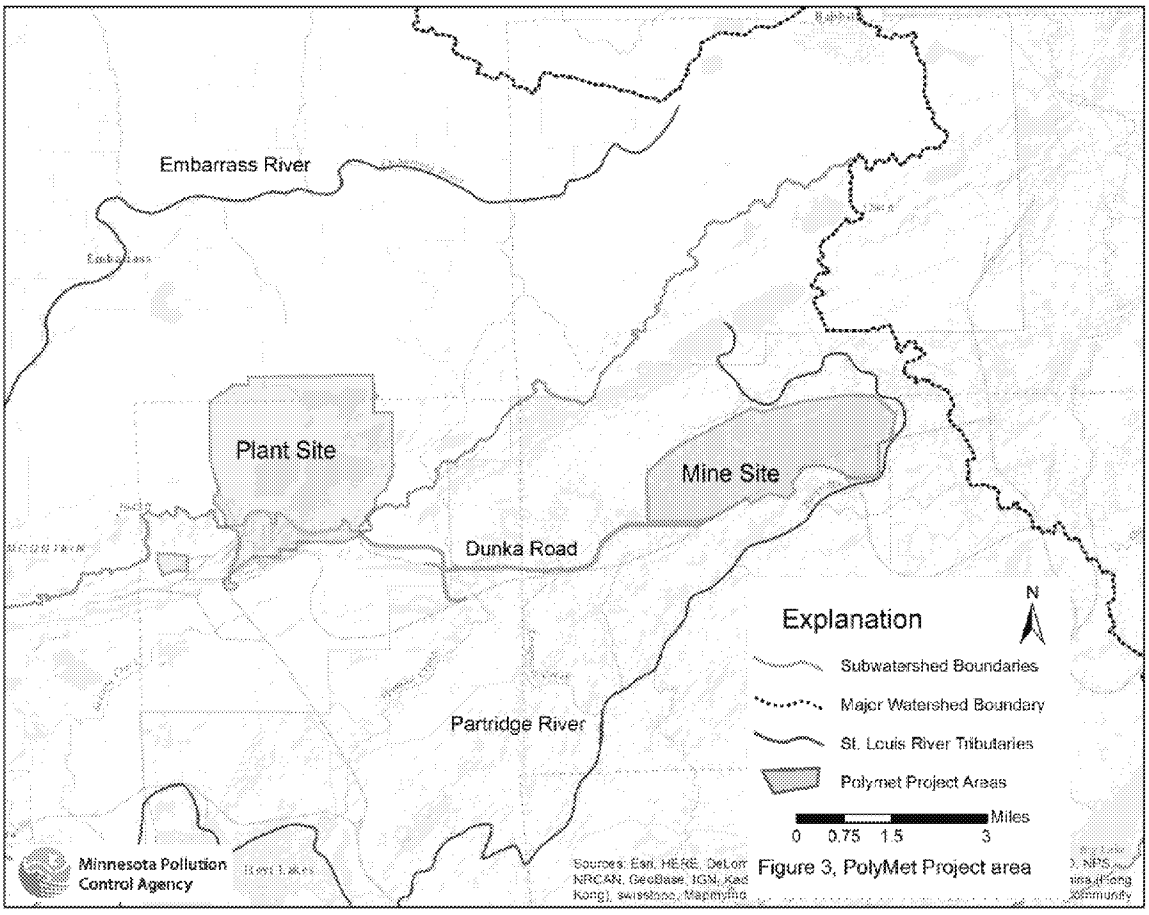


Figure 3, PolyMet Project area

All surface water flow in these subwatersheds is to the St. Louis River. Figure 3 shows the outlines and locations of the PolyMet proposed sites, including the Plant Site, the Mine Site, and the road connection between them (9).

The Mine Site is located in the upper Partridge River watershed in very close proximity to the river. The Plant Site is located on the boundary separating the Partridge from the Embarrass watersheds, with most of the Tailings Basin in the Embarrass River watershed and the Process area in the Partridge River watershed.

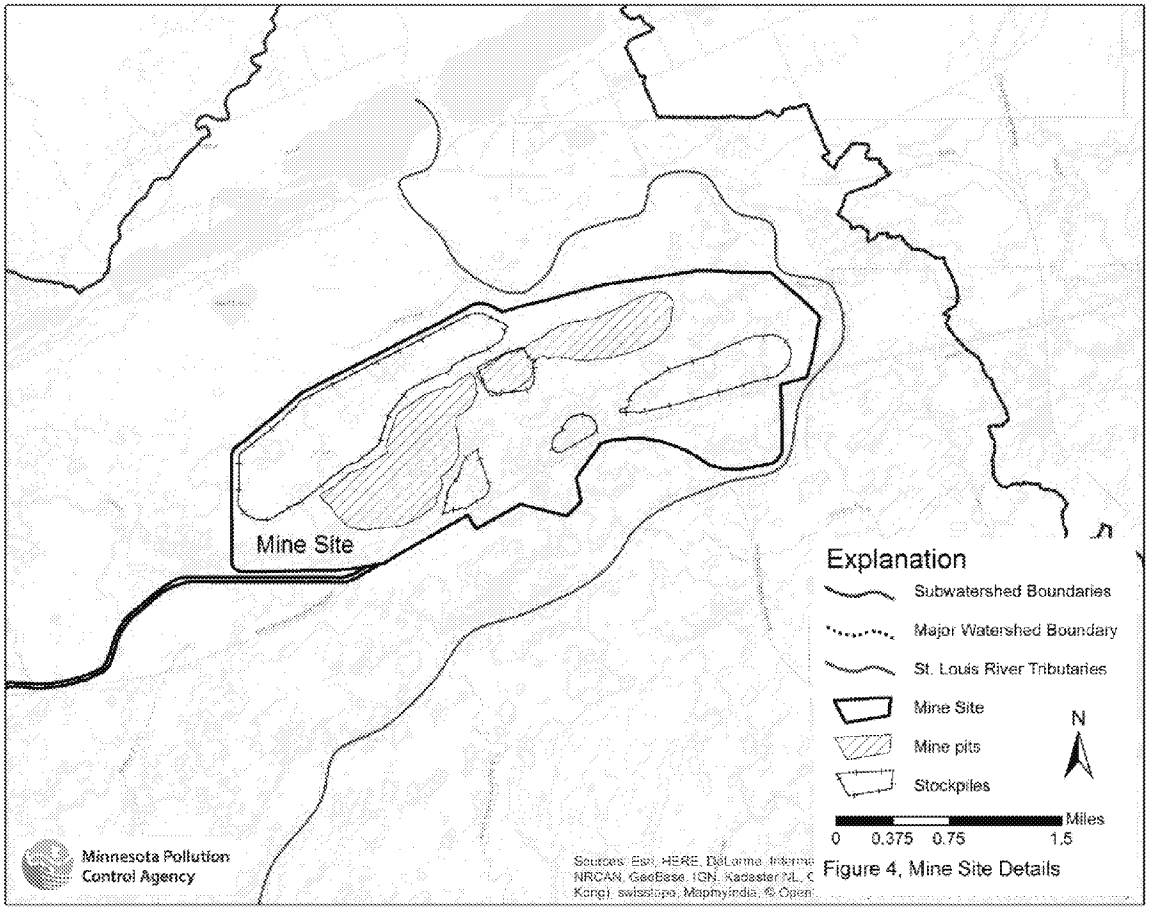


Figure 4, Mine Site Details

Figure 4 provides a close-up of the Mine Site shown in the previous figure. Within the outline of the Mine Site are polygons showing the location of the three mine pits (west, central, and east) and the stockpiles.

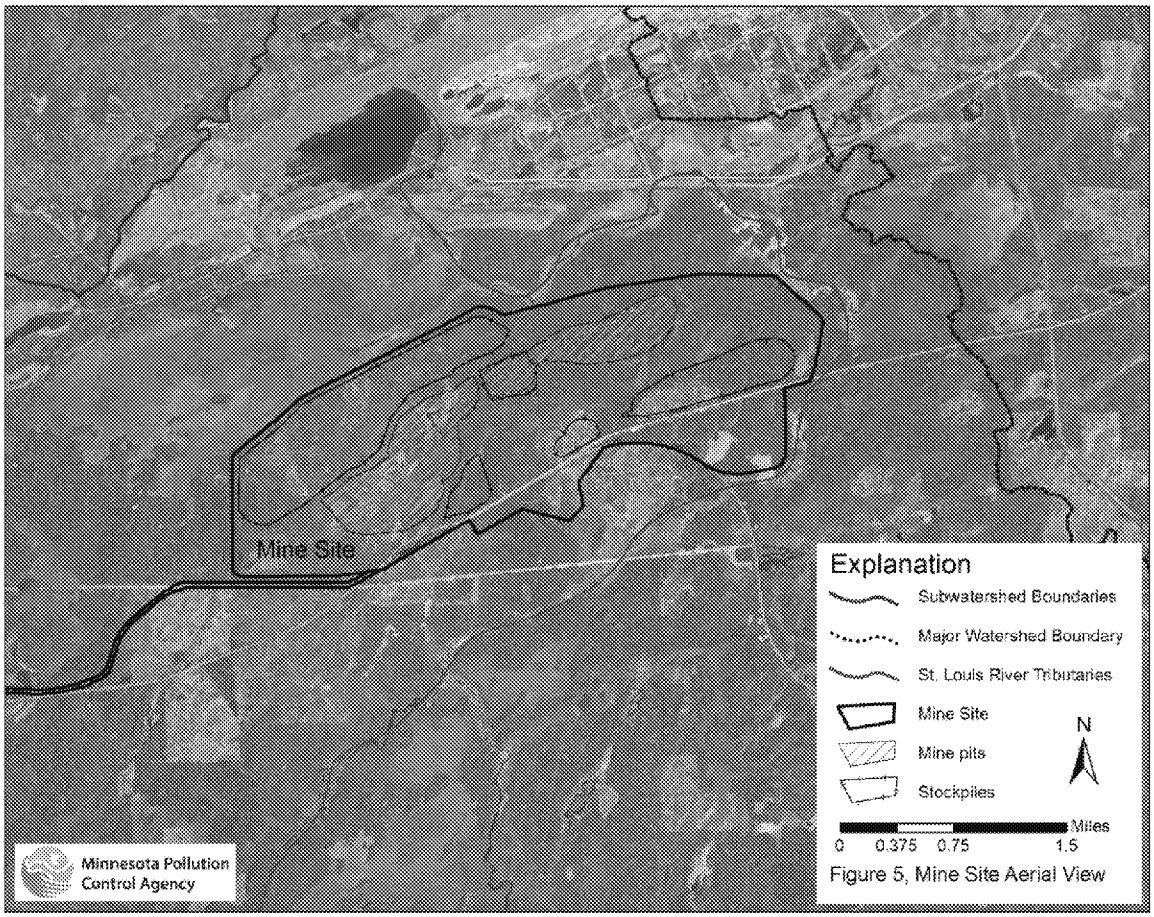


Figure 5 is identical to Figure 4, except now with an aerial photograph as background. This reveals the undeveloped nature of the Mine Site in contrast to the active Peter Mitchell iron mine to the north.

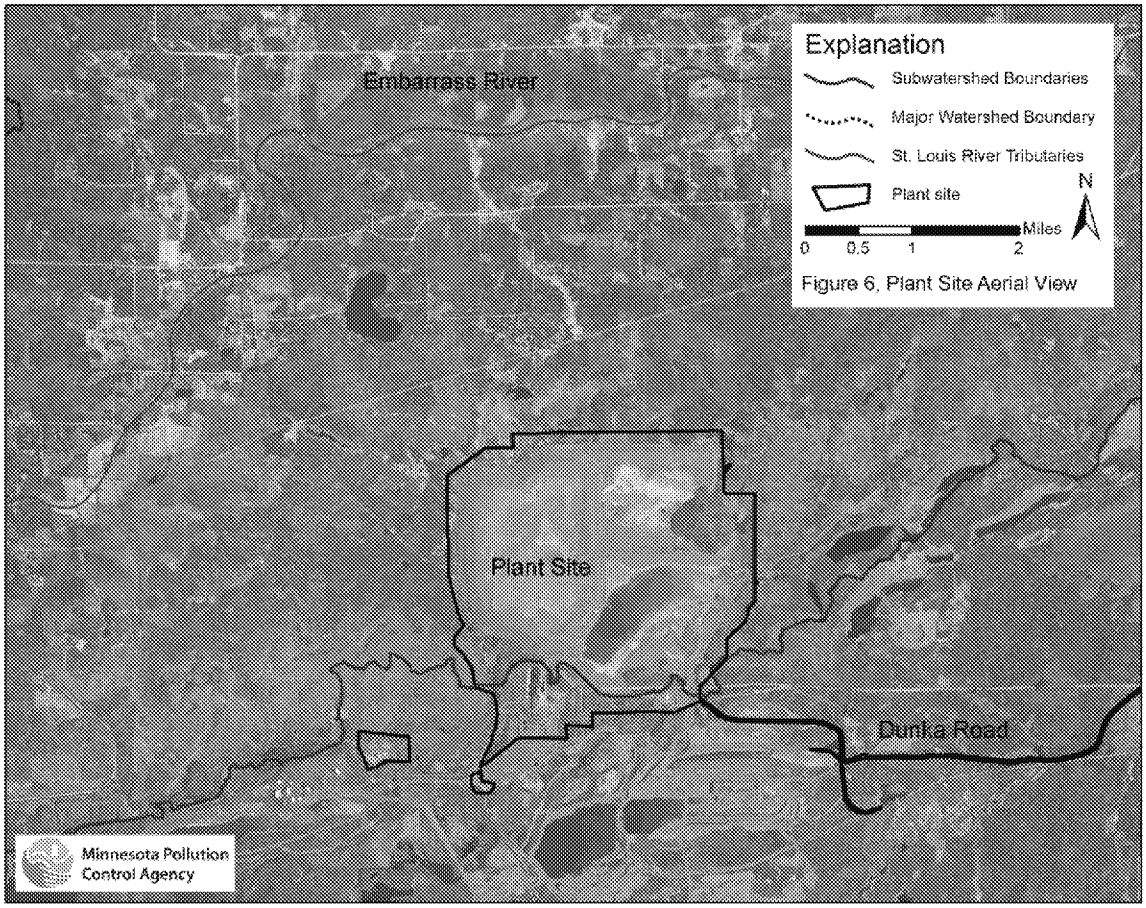


Figure 6 shows the Plant Site with an aerial photograph as background. The Plant Site is disturbed ground that served both as a process area and tailings basin for past iron mining.

Project Area Geomorphology

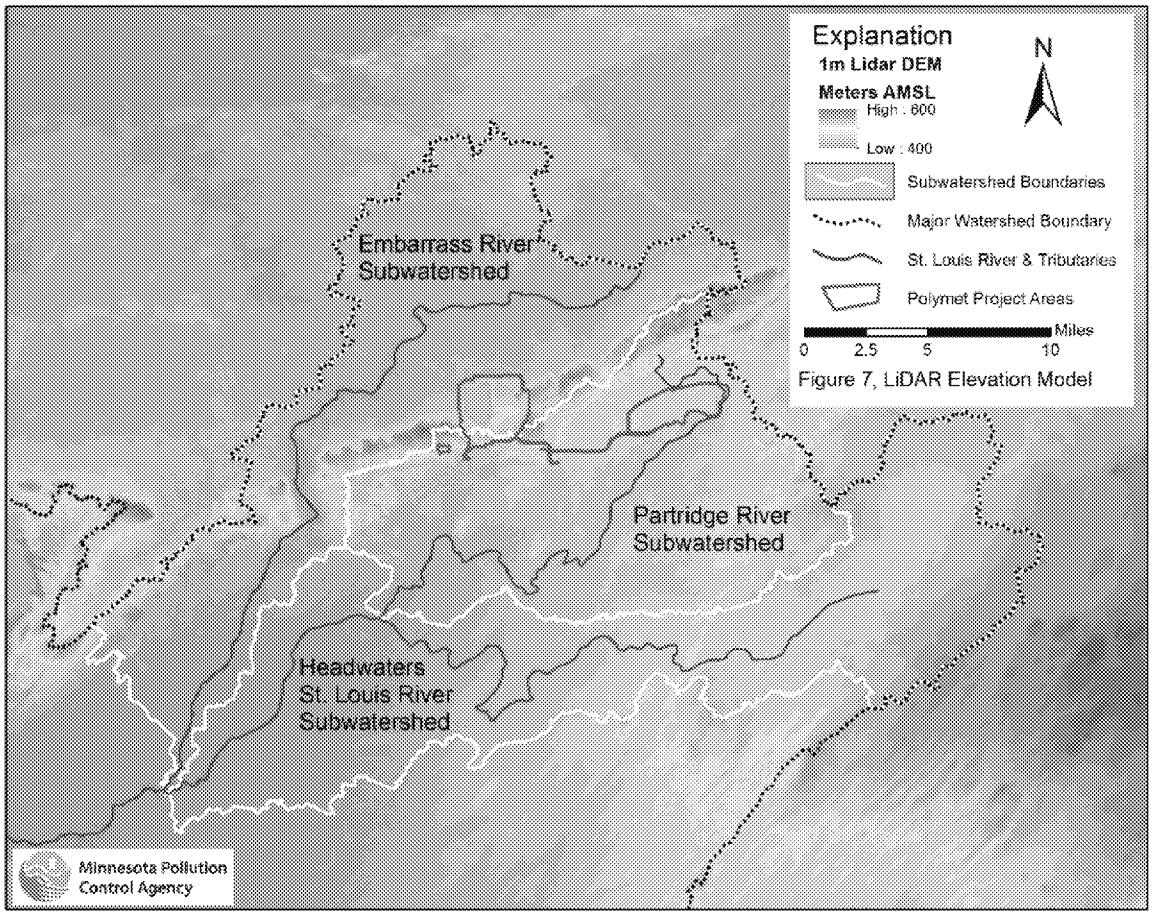


Figure 7 shows the upper watershed with a background of a land surface digital elevation model produced from LiDAR, which stands for Light Detection and Ranging, providing a highly detailed and accurate elevation-based map. Hot colors (dark oranges) are highest elevations and cool colors (dark green) are lowest. Elevations in the area range from approximately 2,000 to 1,300 feet above mean sea level. The highly visible boundary between the Partridge and the Embarrass watersheds is a feature known locally as the Embarrass Mountains, a ridge dominated by granitic bedrock outcrops.

Both the Mining and Plant sites are located along the highest reaches of their respective watersheds, and are located in close proximity to the rivers that define the subwatersheds.

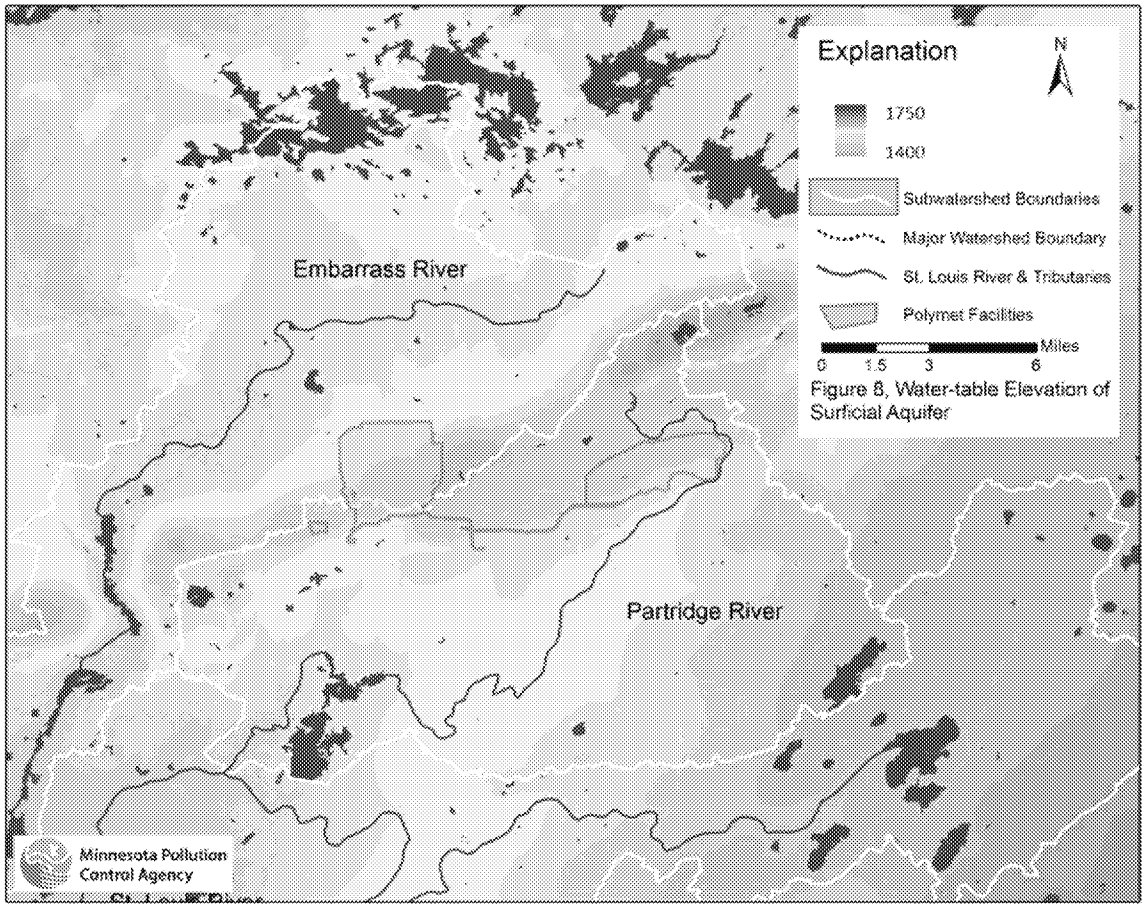


Figure 8 displays the surficial water table, and strongly resembles the previous figure with hot colors representing higher elevations, and cool colors lower elevations. The MN DNR developed this statewide map of water table elevations, and in areas such as this where groundwater information is sparse and bedrock is close to the surface, the map works off the assumption that the water table is strongly influenced by the topography, or surface elevation. This will be discussed further in this report, but indicates that the groundwater shed and the surface water watershed have similar boundaries in portions of the watersheds.

An important observation to mark from this map is that groundwater in the surficial aquifer near the Plant and Mine sites flows away from the watershed boundaries, across the PolyMet sites, and toward the St. Louis River tributaries.

Project Area Surficial Geology

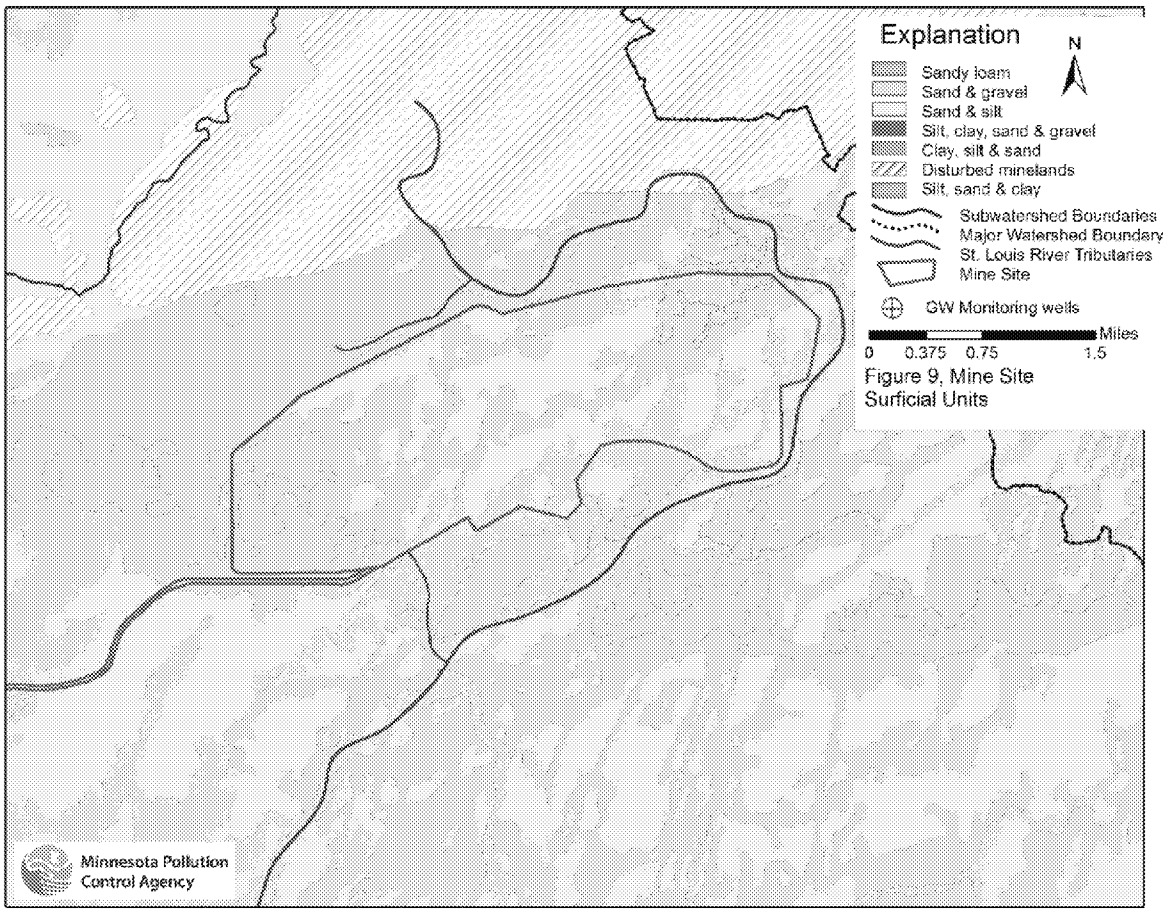


Figure 9 is a map of the surficial geology of the Mine Site. This geologic information is the product of the MGS, and is the first completed mapping of the St. Louis & Lake Counties Geologic Atlas (10). This is a simplified interpretation of the MGS surficial geology map, with sand-dominated and clay-dominated units grouped together. Geologic units dominated by sand are found along the southern boundary of the Mine site, while clay-dominated units are found to the north, in the upper watershed.

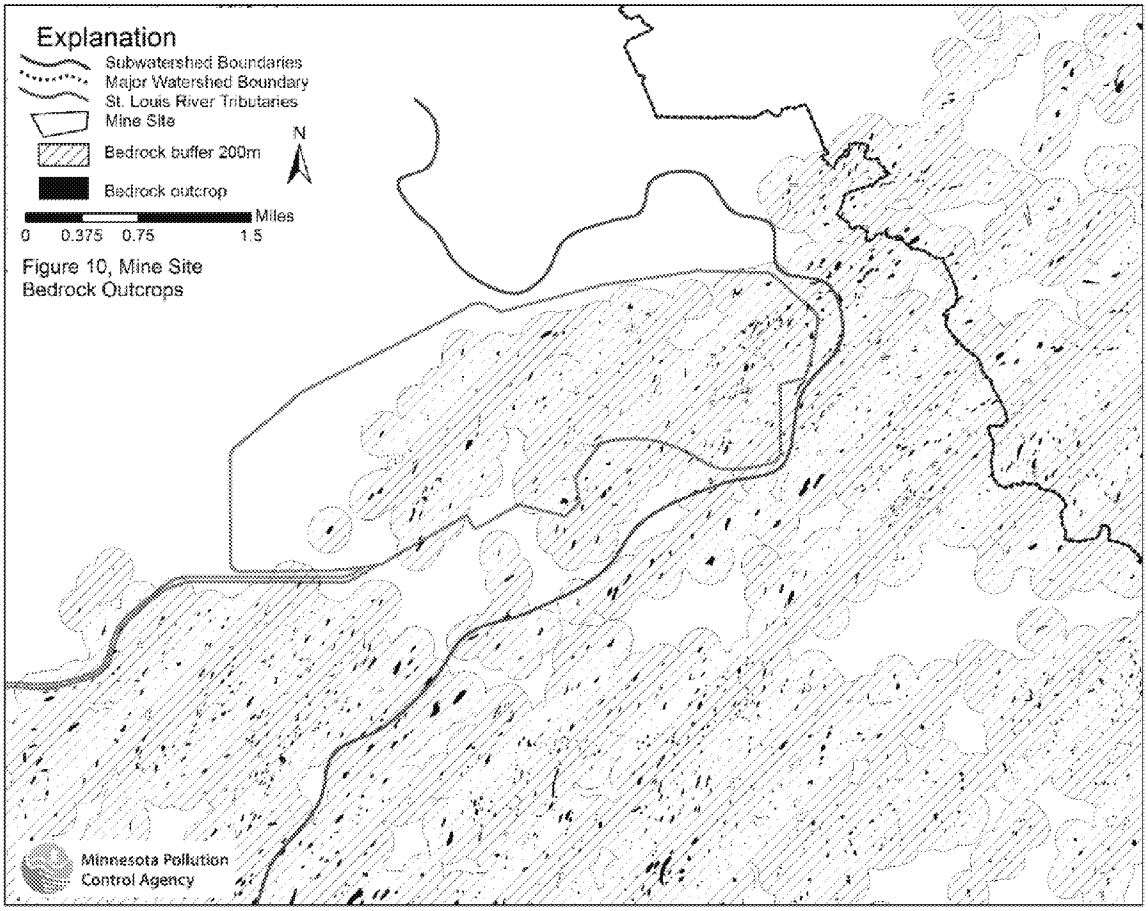


Figure 10 is a display of the Mine Site against a backdrop of a combination bedrock outcrop and depth-to-bedrock map. The MGS surface geology plate's map symbols key states that the bedrock outcrop and buffer patterns both delineate:

> .....regions where bedrock occurs at the surface, as well as where the overlying units are thin (less than ten feet) to bedrock. This was created by using the outcrop database and setting a buffer of 656 feet (200 meters) around each outcrop. Though this buffer is fairly accurate, the actual bedrock topography is extremely variable in this region. There will likely be areas covered by the shading that are greater than ten feet to bedrock, and locations that are less than ten feet to bedrock not covered by the shading.

The thickness of the surficial geology is important because thinner material generally means shorter and faster flow paths as groundwater is restricted to the near surface as it moves to discharge to the tributary streams. Bedrock is at or near the surface throughout the area between the south boundary of the Mine Site and the Partridge River.

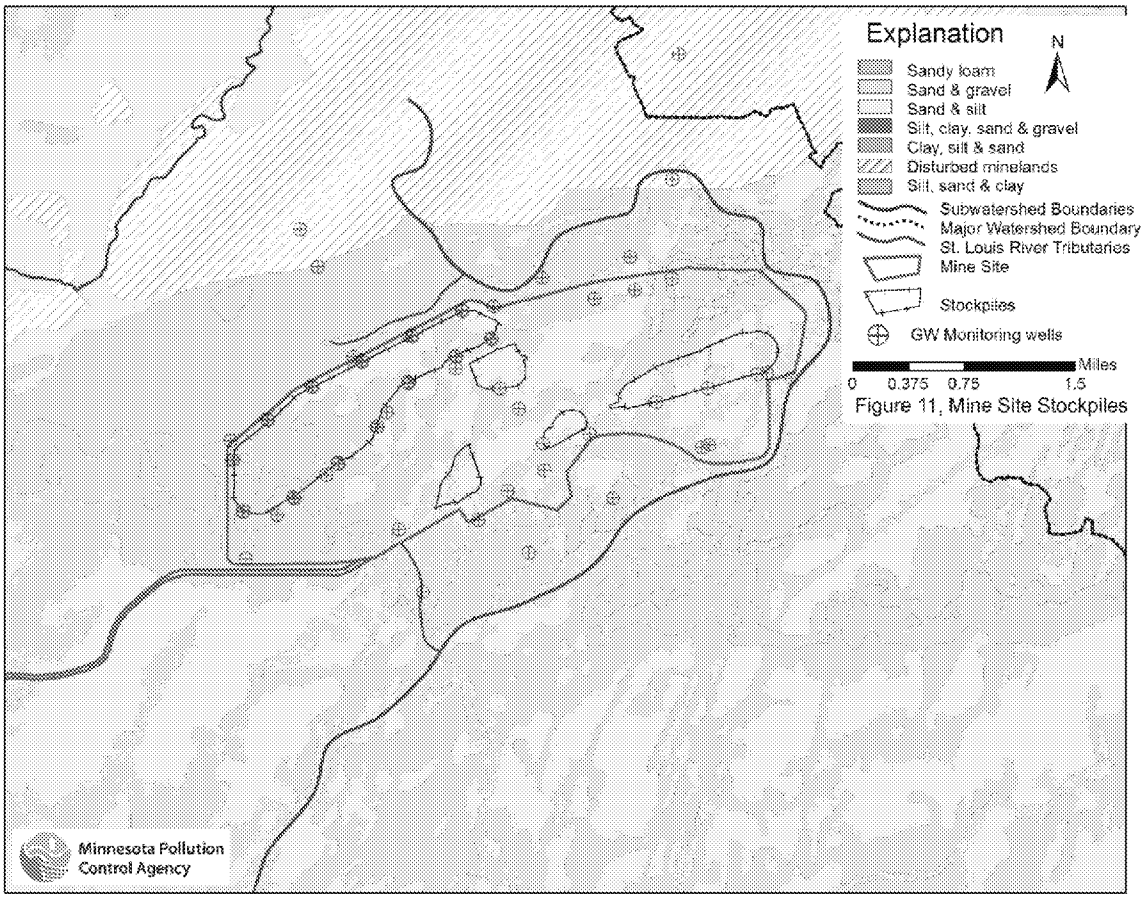


Figure 11 adds all surficial monitoring wells and the outlines of the stockpiles at the Mine Site. The majority of the stockpiles (with the exception of the Category 1 waste rock stockpile in the northwest of the Mine Site) are temporary, to remain in place for 11 – 21 years, and then consolidated into one of the mine pits before the mine closure.

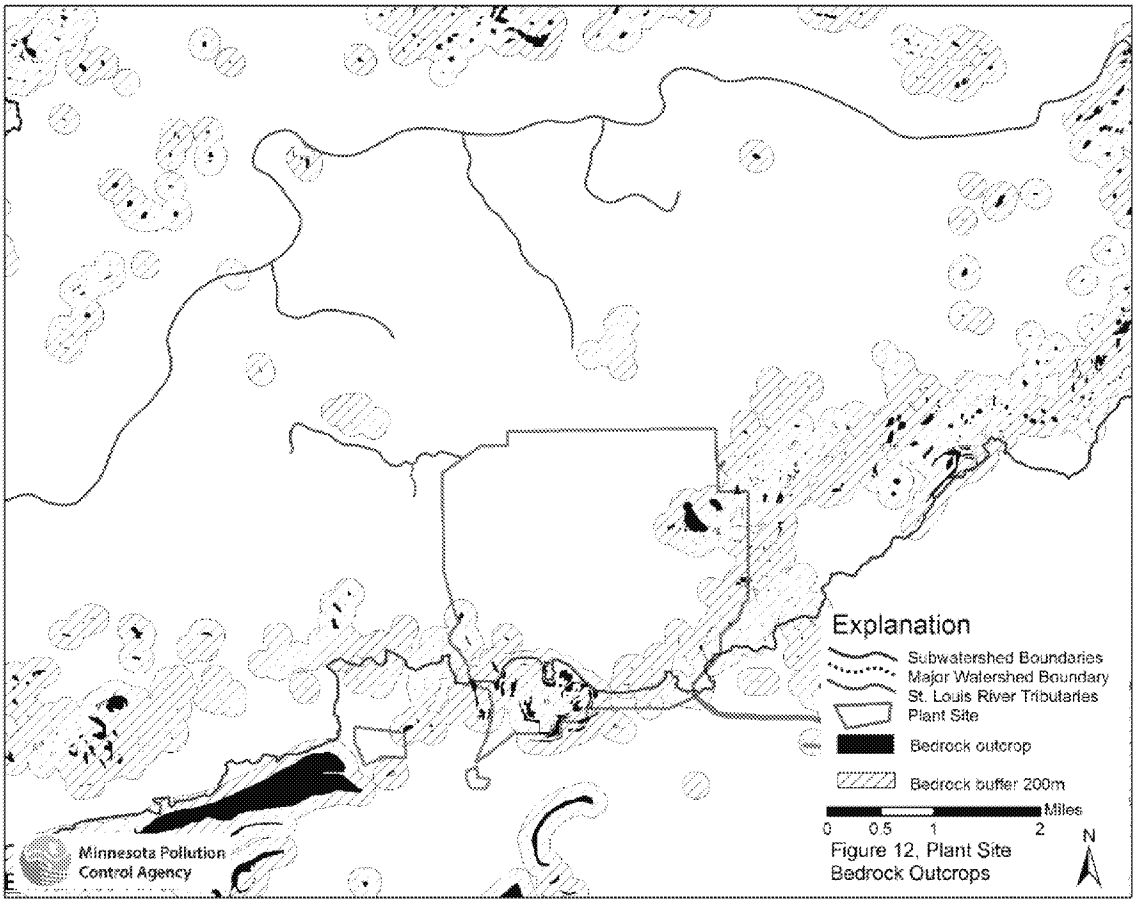


Figure 12. Plant Site Bedrock Outcrops

Turning to the Plant site, Figure 12 shows the bedrock outcrop and buffer analyses for the area. Bedrock and shallow surficial material can be found along the watershed boundary that divides the Plant site from the Tailings Basin. From this map it is clear that the thickness of surficial geologic material increases to more than 10 feet north and west of the tailings basin, in the downgradient groundwater flow direction toward the Embarrass River.

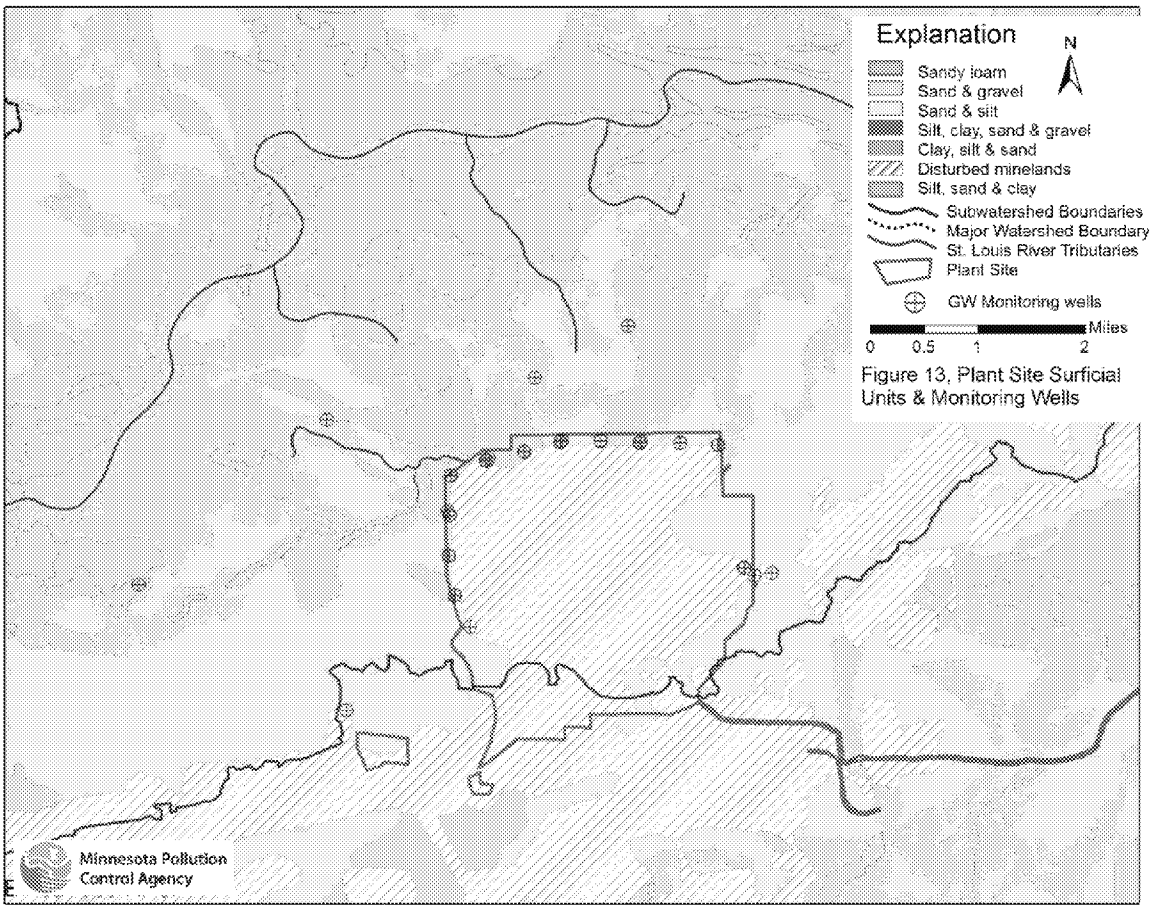


Figure 13, Plant Site Surficial Units & Monitoring Wells

The Plant site surficial geology, with monitoring wells is displayed as Figure 13. Much of the tailings basin area has been extensively disturbed by past mining activity.

Project Area Bedrock Geology

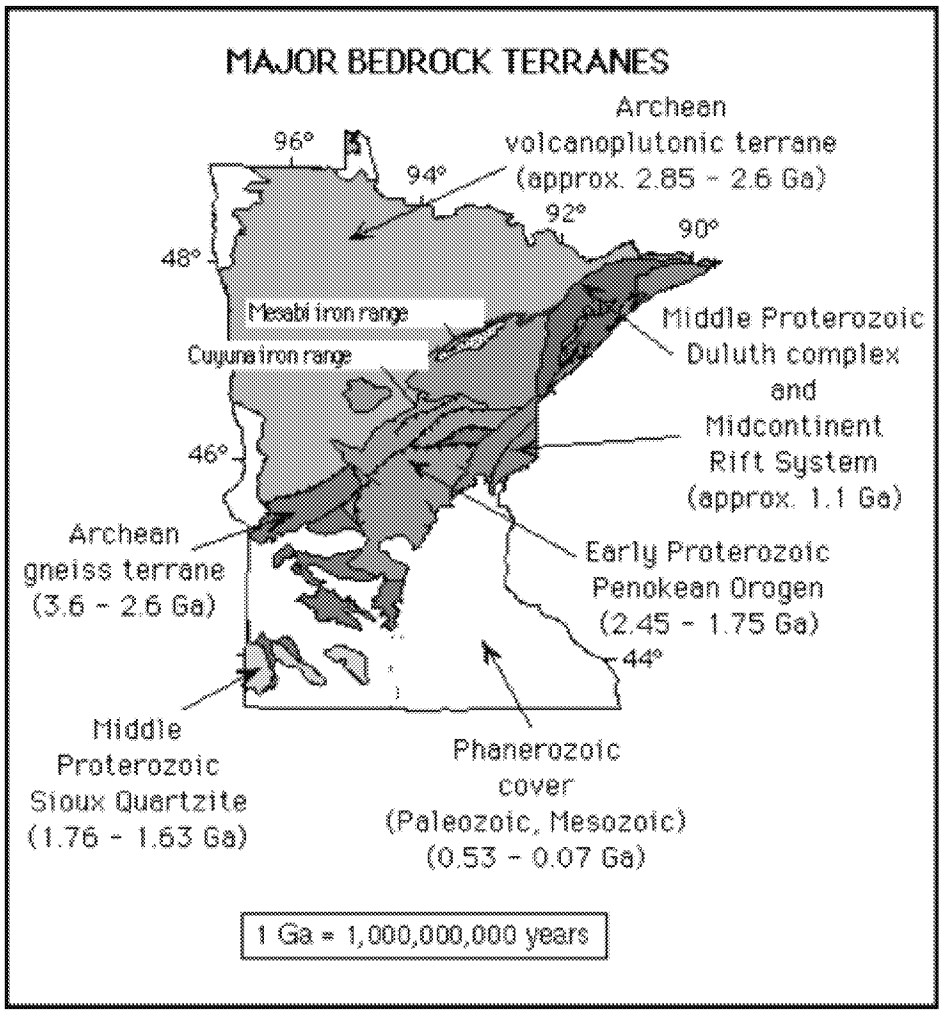


Figure 14, Minnesota's Bedrock Regions (11)

The bedrock underlying the PolyMet site is a very different geologic environment from the overlying surficial material. Where the surficial geology is the product of glaciation that occurred less than 10,000 years ago, the bedrock is over 1 billion years old. (Figure 14).

The Duluth Complex and the associated North Shore Volcanic Group are rock formations that comprise much of the basement bedrock of the northeastern part of Minnesota. Both formations are igneous rocks formed during the Midcontinent Rift. The Duluth Complex is a composite intrusion of troctolite and gabbro derived from periodic tapping of an evolving magma source. This rock is dense, and in the region of the PolyMet project area it has near-surface fracturing. These fractures are not mapped, and their hydrologic properties are little understood. From personal communication with one of the MGS report authors:

> ..... the nature of faults and other fractures in bedrock is poorly known. The only "ground truth" are the joint measurements we made on outcrops, but that data set was not released with the open-file report. Even with those data, establishing depth of penetration and interconnectedness of fractures is nearly impossible to establish without very precise and detailed (site-specific) information. It is generally logical to infer that joint spacing and connectedness decreases with depth ..... In the end, the only absolute way to assess continuity

of fractures is to drill patterns of holes so closely spaced that the rock is turned to swiss cheese. Adding complexity to these questions is literature that reports deeply weathered faults and fractures that were altered to clay minerals (saprolite) can actually behave as aquitards.

Though little is known about groundwater flow through the bedrock, it is assumed to be limited by the narrow fractures and the potential for infilling by low transmissive materials. Because of this poorly understood fracture-based porosity, the decision was made by PolyMet to initially install wells only in the overlying surficial geologic material. (Some of the wells identified as bedrock wells in the project report are actually screened above the bedrock/surficial material interface.) This can be a successful strategy because bedrock flow in this area is often strongly influenced by the flow in the overlying surficial materials. As discussed previously in this report about groundwater flow in the surficial material, this would lead to the conclusion that the best assumption of groundwater flow behavior in the bedrock is that it mimics flow directions in the surficial unit. Combined with the previous discussion about the lack of surficial material along much of the Embarrass and Partridge watershed boundary, groundwater flow in the bedrock system is assumed to be constrained by surface water watershed boundaries. To clarify, that means that it is assumed in this report that groundwater that is found in one watershed will remain in that watershed through to discharge to the watershed river.

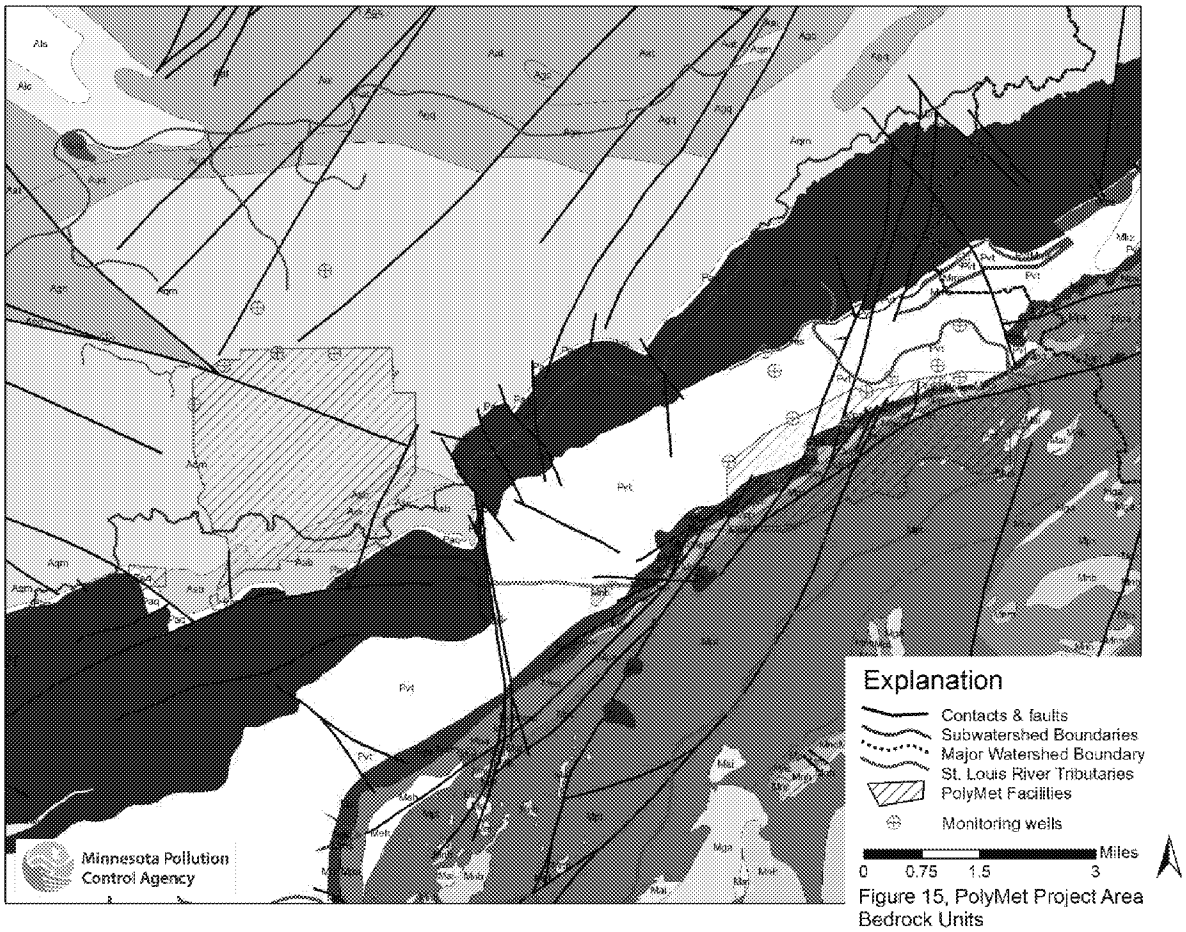


Figure 15, PolyMet Project Area Bedrock Units

Figure 15 shows the bedrock units as mapped by the MGS for the entire PolyMet process area. Contacts & faults, monitoring wells, and individual rock unit codes are included in this display (12). A full explanation of all rock unit codes can be found in the MGS Bedrock report (12). Included in the map are contacts and faults, the hatched outlines of the PolyMet facilities, and the locations of key monitoring wells, including those identified as bedrock wells at the Mine Site.

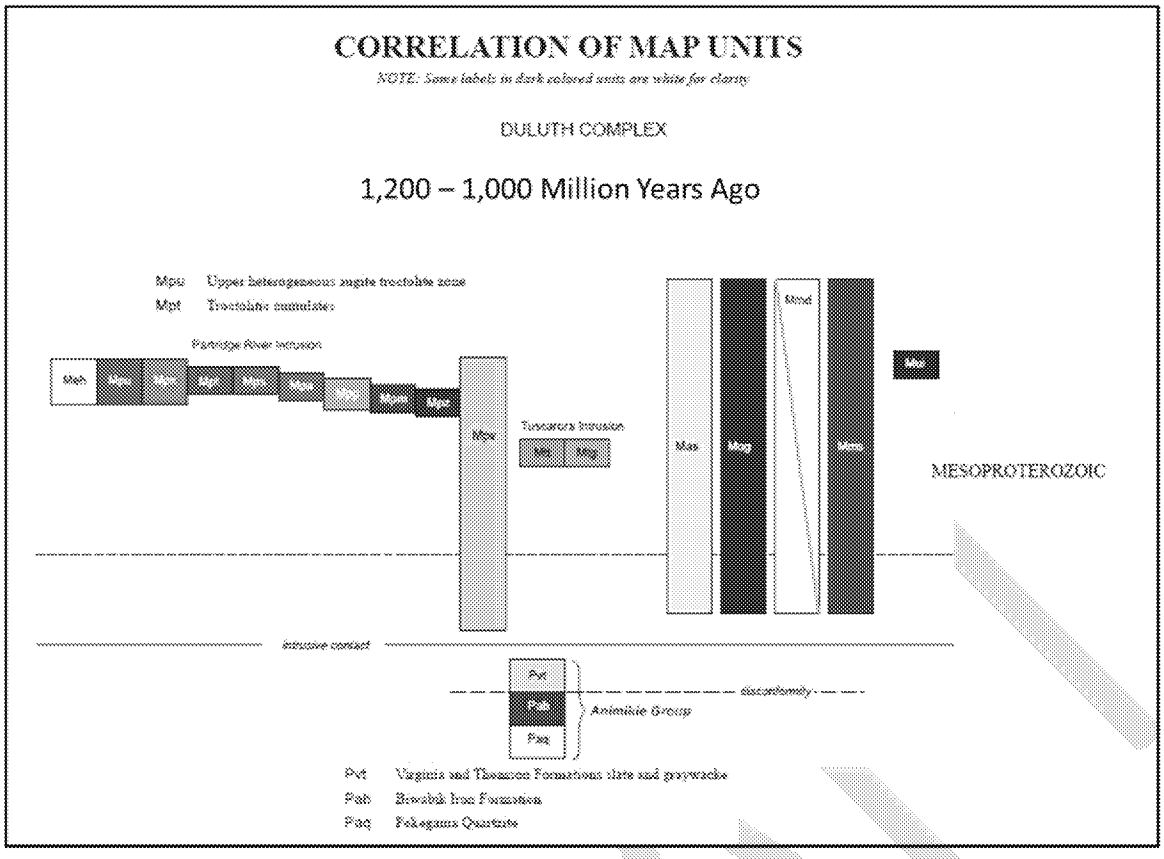


Figure 16, Minnesota's Bedrock Regions, Source MN Geological Survey

A small subset of relevant unit codes from Figure 15 are presented in Figure 16.

Further complicating the review of groundwater flow in the bedrock units, according to the MGS map authors in a personal communication, the location and length of each fault in Figure 15 is only an estimate:

> Th(e) level of accuracy at this map scale (plus or minus a hundred feet or more) is typical for even the best exposed bedrock areas…..(O)utcrop …….. represents something less than 2% of the land surface in the arrowhead region. …. the best gauge of accuracy is the data density. Faults are rarely exposed, as they tend to weather recessively. If the mapped fault has outcrops on its flanks, it's pretty well constrained (but still possibly 100' or so accuracy). The fault in question is likely based on offset of units using drill core, then extended with some certainty using lidar or other more remote-sensed data--best that can be done with at this scale with the data at hand.

The location of the faults in this map cannot therefore be used to determine the presence of potential preferential pathways for groundwater, because too little is known of the actual location and orientation of the faults themselves.

D. Monitoring Well Review

Compliance monitoring of groundwater is defined in Volume 1, Section 3.1, page 32 of the PolyMet NPDES/SDS permit application (13) as:

> Compliance Monitoring (groundwater): Compliance monitoring will be conducted at locations where the Project will need to demonstrate compliance. These locations are downgradient of potential Project impacts. Groundwater compliance monitoring stations are typically at or near the property boundaries.

The compliance network of monitoring wells and their placement was therefore judged on their efficacy for intercepting potential contaminated groundwater released from the PolyMet facilities. Potential gaps in the coverage will be identified and new locations of monitoring wells proposed.

As discussed earlier, there are limited wells completed into the bedrock because any flow would be restricted to the small and unmapped fractures. This flow, where it exists at all, is assumed to be minor. Wells constructed to monitor possible bedrock flow are therefore screened at the top of the bedrock surface where they may be an interaction of groundwater flow from the surficial and bedrock geology.

The effectiveness of the placement of monitoring wells in the PolyMet application can be assessed by combining information from the previous slides on thickness, geologic make-up, and groundwater flow directions. Monitoring wells are placed to provide early detection of contaminated groundwater leaving one of the Mine site facilities. Generally, monitoring wells should be located between the facilities of concern and the surface discharge point for the local, surficial groundwater system. Where possible these wells should be placed into sand-dominated surficial geologic units because such units convey larger volumes of groundwater faster to surface water discharge points. These are pathways that are best suited for monitoring wells.

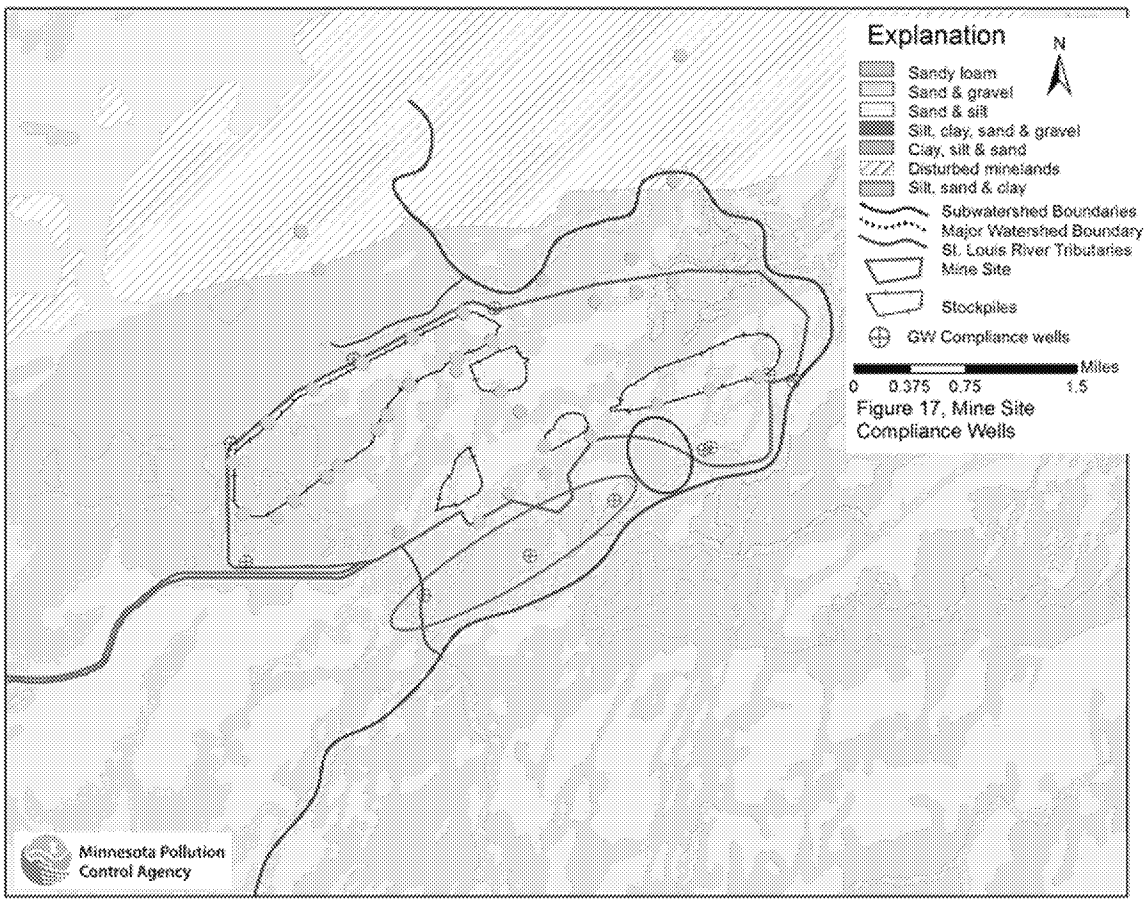
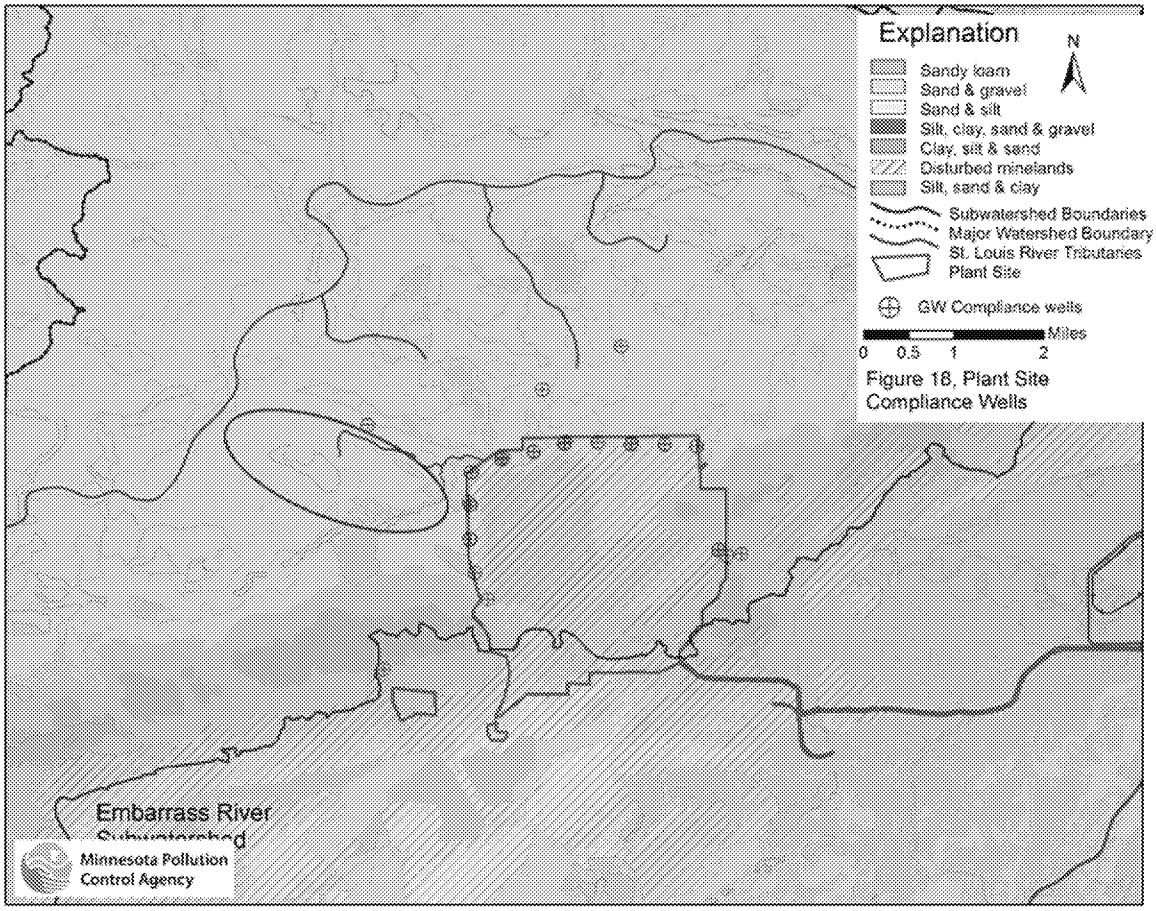


Figure 17 shows a close-up of the Mine site area with property boundary monitoring wells identified as blue crosses within circles. Other monitoring wells in the region are shown as lighter blue dots. A first observation is that while there are monitoring wells located within a half mile of the southern boundaries of the stockpiles, the three wells lying closest to the Partridge River south of the stockpiles are completed in clay-dominated geologic units, or are located upgradient of clay-dominated units (blue oval). Groundwater flow through clay-dominated materials is much slower than sand-dominated materials, and so wells completed along pathways dominated by clay are less likely to provide early warning

of a release of contaminated groundwater. This would make reliance on such wells less desirable for use as compliance wells. Alternately, a sand-dominated expanse (red oval) that represents a preferential groundwater flowpath to the Partridge River is not monitored. A monitoring well to be located in this area has since been proposed by PolyMet and is expected to be included in the NPDES/SDS permit for the Project.



It was determined earlier in the report that groundwater flows north across the former tailings basin toward the Embarrass River and its tributaries. Compliance wells displayed in Figure 18 should be evaluated for their ability to intersect groundwater flowing toward these streams. As with Figure 17, the three property boundary monitoring wells are represented by dark blue crosses inside of blue circles, while all other wells are shown as light blue dots. The LiDAR component of surface elevation is included to indicate with dark shading where surface elevations are highest, to indicate areas less likely to be a preferential flowpath. There is one compliance well to the northwest of the Plant site. According to the MGS geologic map, this well is located near the boundary between sand-dominated subsurface materials and clay-dominated geologic materials. If the well is constructed in clayey materials, the probability that it will effectively monitor Project groundwater impacts is reduced. The large area encompassed by the red oval that lies between Unnamed Creek and the highlands to the south is an area that could be considered for an additional monitoring well if a review of the existing well suggests that it is not an effective downgradient monitoring point (and assuming property ownership and access are amenable). Monitoring of the existing well and an annual assessment of its suitability is expected to be included in the NPDES/SDS permit for the Project. The two wells north of the tailings basin are completed in sand-dominated materials and appear to be appropriately located.

Any new wells installed to compliment the existing well network should be constructed as well nests. A nest can be as few as two wells in close areal proximity to each other. The deeper well's screen base should be set against the bedrock surface and should extend up-column 2 to 4 feet. The shallower well should be screened across the most permeable section of the aquifer as determined from the well log. This configuration will allow a higher probability of intercepting any contaminated groundwater flowing toward the Embarrass River and its tributaries.

E. Statistical Determination of a Groundwater Release

The PolyMet nondegradation application asserts that groundwater has a low probability of escape from the engineered containment systems that will be employed at the PolyMet project areas. In the case of the Mine Site this includes the temporary waste rock and ore stockpiles, the overburden storage and laydown area, the wastewater treatment system equalization basins, the mine pits, mine water sumps, and overflow ponds. The language used is (14):

> Each of the Mine Site features with the potential to affect groundwater will be constructed and managed to maintain natural groundwater quality to the maximum practicable extent.

And

> PolyMet will monitor the performance of the Mine Site engineering controls and the groundwater quality downgradient of Mine Site features (Section 3.2.1 of Volume I) to meet the maximum practicable extent requirements of Minnesota Rules, chapter 7060, and if the engineering controls are not achieving the desired outcomes, will implement adaptive management actions or contingency mitigation (Sections 6.5 and 6.6 of Reference (2)), as necessary to comply with all permit conditions. (NPDES/SDS Permit App – Vol II, Mine Site, section 4.4)

Also included is a table with predicted arrival times for contaminated groundwater for different elements of the Mine Site from the same volume (15):

Table 4-1 Estimated Flow from Potential Sources of Groundwater Impacts

Contaminant Source	Flow Rate (gpm)	Duration of Source (Mine Years)	Mine Year when Solute Plume First Arrives at Partridge River
East/Central Pit	3.75(1)	20+	100
West Pit	6.09(1)	48+	105
Category 2/3 Waste Rock Stockpile (Temporary)	0.0193	0-20	35
Ore Surge Pile (Temporary)	0.00116	0-21	90
Waste Water Treatment Facility (WWTF) Equalization Basins	0.0138	0-33	85
Overburden Storage and Laydown Area	14.0	0-20	30(2)

Information from Table 5.2.2-27 of Reference (8), based on GoldSim deterministic run with 50th percentile inputs. See Section 3.0 of Reference (4) for a description of the GoldSim modeling.

(1) Pit water into groundwater flow path

(2) Concentration decrease

Nonparametric Sign Test and Signed-Rank Test

The concept of 'solute plume' that is used in the table above can be assumed to refer to a concentration of a parameter or parameters related to sulfide deposits or other compounds related to the area parent rock that are found in groundwater, and is/are greater than the recorded values in wells before the beginning of mining. But how much greater? It is common in technical studies to answer this question with statistical tools that determine the point when a particular dataset differs in a statistically significant fashion from another dataset. For the PolyMet wells, the datasets would be water quality samples taken from wells before mining, and then again after the start of mining. The recommended statistical tests for such paired results (before and after) are the sign test and the signed-rank test. (16). The use of these tests are outlined in a hydrology handbook developed by the United States Geological Survey entitled, "Statistical Methods in Water Resources", by D.R. Helsel (17). Using the tests' procedures, the pairs of water quality results are compared for signs of differences, a check on the assumption that the engineering controls are achieving nondegradation of groundwater as predicted in the above table. These nonparametric tests are more appropriate to environmental data than parametric statistics that assume normally distributed datasets. The suggested p level employed would be $\alpha = 0.05$ significance level. Another way of saying this is that we want the probability that the difference between the datasets is not due to chance to be 95% or greater.

It is recommended that MPCA review of groundwater monitoring data incorporate appropriate statistical methodologies and that if the draft permit requires PolyMet to submit a periodic groundwater monitoring report, that it requires that report to describe the statistical tests that were employed.

F. Conclusions.

Groundwater flow in the surficial aquifer of the PolyMet project area is controlled by the geomorphology of the upper St. Louis River Watershed within which it is found. Groundwater sheds and surface watersheds coincide due to the presence of thin sequences of surficial material and the dense nature of the underlying bedrock. Groundwater flow in both aquifers, in both the Embarrass and Partridge River watersheds, is assumed to remain within each watershed before discharging to surface water.

There are several recommendations that can be made based on this technical review of the PolyMet application. The first is that there is a need for a new property boundary monitoring well(s) south of the Mine site, in the area shown in Figure 17. There are also areas downgradient of the Tailings Basin in the Embarrass River watershed that could similarly be covered with a new monitoring well if any existing wells are found to be ineffective, as shown in Figure 18. New wells should be placed in well nests, with a deep well screened above the bedrock/surficial geology interface, and a shallower well screened either across the water table or across the most permeable section of the aquifer if demonstrated to more appropriate.

A nonparametric statistical test such as the sign or the signed-rank could be employed to determine when post-mining water quality results differ from pre-mining concentrations to a statistically significant level. These recommendations are made to meet the requirements of the groundwater nondegradation policy as outlined in Minnesota Rule 7060.0500.

References

(1) Minnesota Rule 7050, surface water; https://www.revisor.mn.gov/rules/?id=7050
(2) Minnesota Rule 7060, groundwater; https://www.revisor.mn.gov/rules/?id=7060

(3) MPCA Surface Water Anti-degradation response; \\x1600\xdrive\Agency_Files\Mining Sector\NorthMet\Non-Deg\Anti-Degradation-11.docx

(4) PolyMet NPDES Permit Application, Volume 2, Table 1-2, page 18; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20II%20-%20Mine%20Site%20v1%20JUL2016.pdf

(5) PolyMet NPDES Permit Application, Volume 5, Table 1-2, page 12: https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20V%20%E2%80%93%20Tailings%20Basin%20and%20Beneficiation%20Plant%20v1%20JUL2016.pdf

(6) MPCA site, Water Quality Permit for NorthMet; https://www.pca.state.mn.us/quick-links/water-quality-permit-northmet

(7) PolyMet NPDES Permit Application, Volume 5, Tables 3-4, 3-5, and 3-6; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20V%20%E2%80%93%20Tailings%20Basin%20and%20Beneficiation%20Plant%20v1%20JUL2016.pdf

(8) PolyMet NPDES Permit Application, Volume 6, Large Figure #3; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20Vol%20VI%E2%80%93HRF%20and%20Hydrometallurgical%20Plant%20v1%20JUL2016.pdf

(9) PolyMet NPDES Permit Application, Volume 2, Section 4.3.2; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20II%20-%20Mine%20Site%20v1%20JUL2016.pdf

(10) Minnesota Geological Survey, surficial geologic map of the Central Arrowhead Area, Lake and St. Louis Counties, northeastern Minnesota; http://conservancy.umn.edu/bitstream/handle/11299/183258/SurfaceGeologyPlate.pdf?sequence=2&isAllowed=y, and (http://hdl.handle.net/11299/183258)

(11) Mineral potential and geology of Paleozoic and Mesozoic rocks in Minnesota, MGS Report: http://www.mngs.umn.edu/mnpot/paleozoic.html.

(12) Minnesota Geological Survey, bedrock geologic map of the Central Arrowhead Area, Lake and St. Louis Counties, northeastern Minnesota; http://conservancy.umn.edu/bitstream/handle/11299/183258/BedrockGeologyPlate.pdf?sequence=5&isAllowed=y

(13) PolyMet NPDES Permit Application, Volume 1, Section 3.1, page 32; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20I%20%E2%80%93%20Introduction%20v1%20JUL2016.pdf

(14) PolyMet NPDES Permit Application, Volume 2, Section 4.4; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20II%20-%20Mine%20Site%20v1%20JUL2016.pdf

(15) PolyMet NPDES Permit Application, Volume 2, Section 4.4, Table 4-1, page 52; https://www.pca.state.mn.us/sites/default/files/NPDES-SDS%20Permit%20App%20-%20Vol%20II%20-%20Mine%20Site%20v1%20JUL2016.pdf

(16) Statistical tests; https://en.wikipedia.org/wiki/Sign_test, https://en.wikipedia.org/wiki/Wilcoxon_signed-rank_test

(17) Statistical Methods in Water Resources, Chapter 6, Matched-pair Tests, page 137 (US Geological Survey); https://pubs.usgs.gov/twri/twri4a3/pdf/twri4a3-new.pdf

(18) Mapping resources from Minnesota Geospatial Commons, MPCA GIS Services, and Barr Engineering.

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